Multilayer Coatings for Constellation-X

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Approach:

•**Replace the baseline iridium SXT mirror coatings with multilayers**

Benefits:

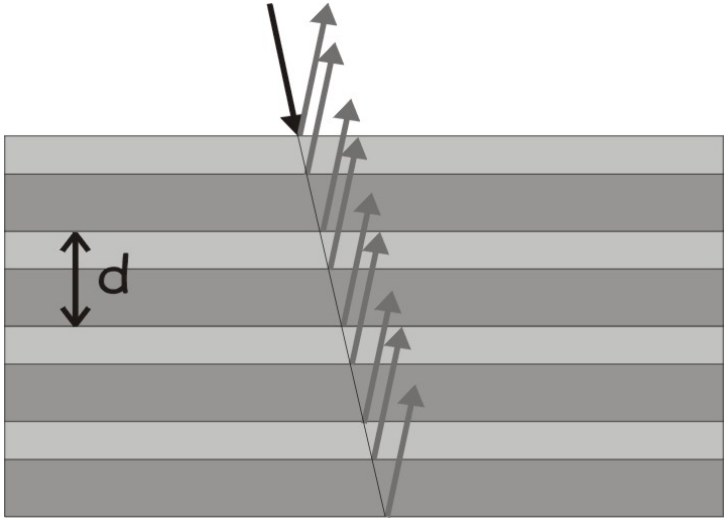
•*Enhanced throughput over the nominal 0.3 – 10 keV bandpass*

•*Extended response to 40 keV*

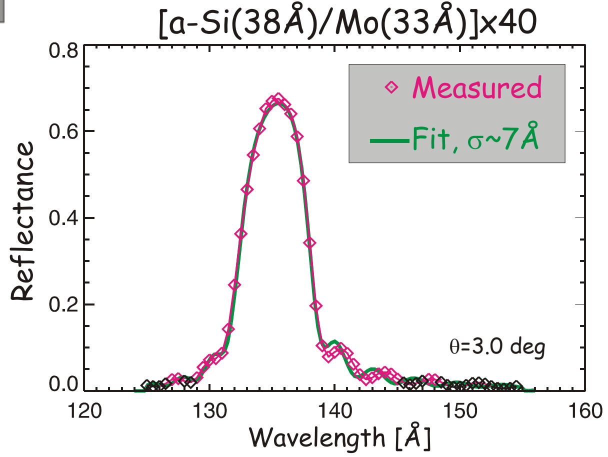
Costs:

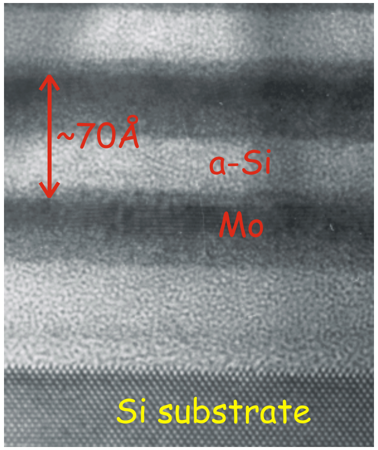
•*Not so much…*

Periodic Multilayers: use constructive interference between reflections from each interface in the layer stack to provide high reflectance, as per Bragg's law ($n\lambda=2d\sin\theta$)

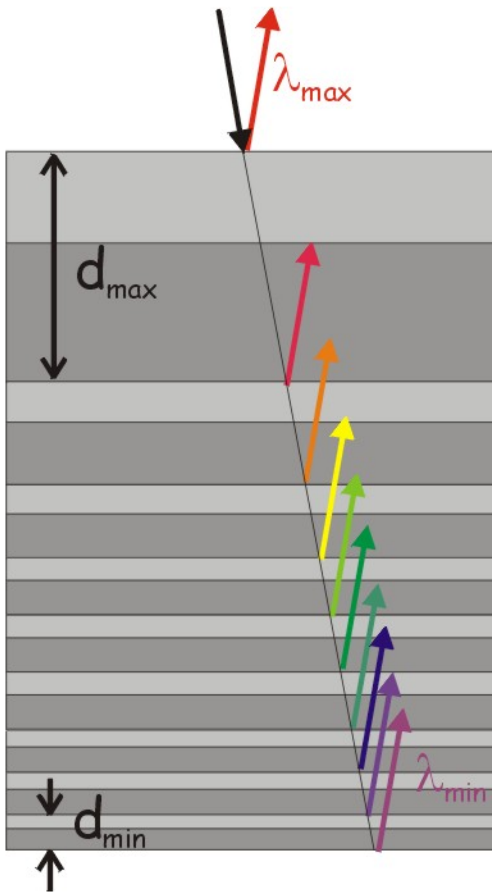


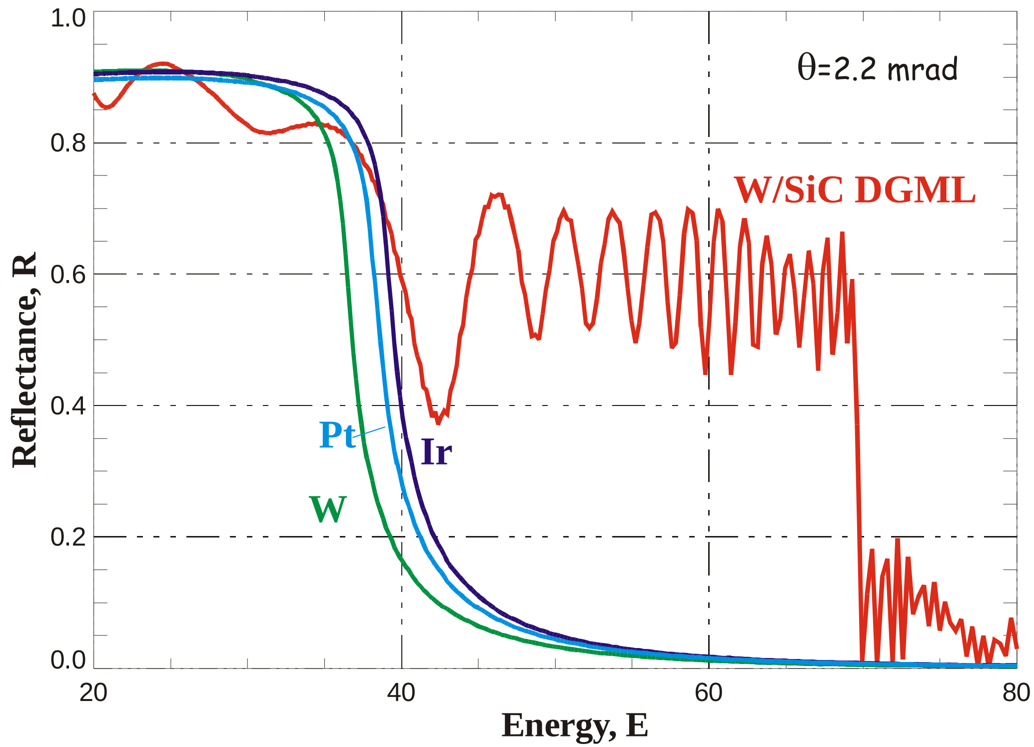
The Bragg condition is satisfied only over a narrow range of angles and wavelengths (energies).

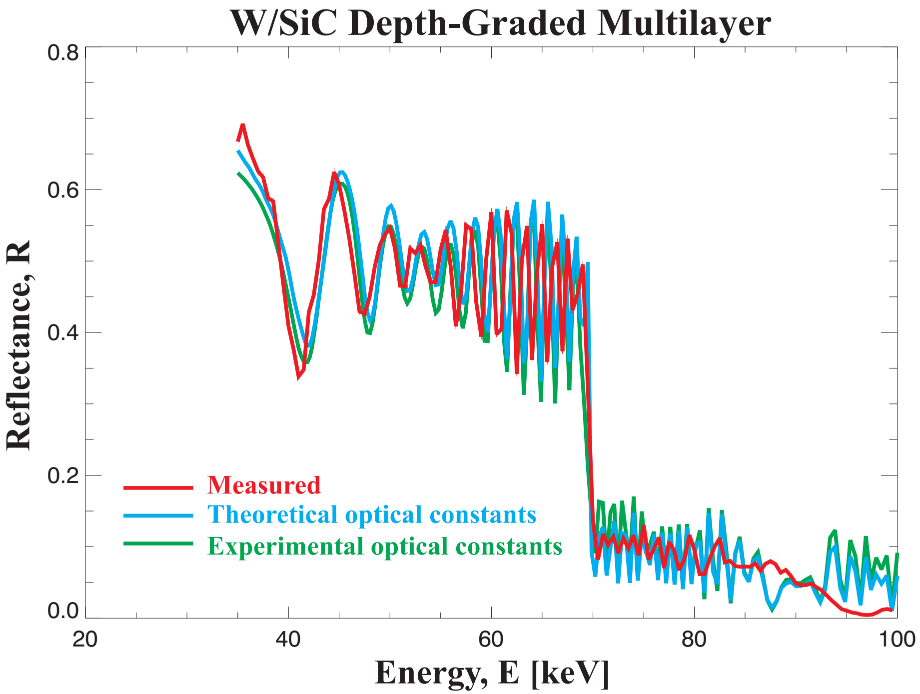


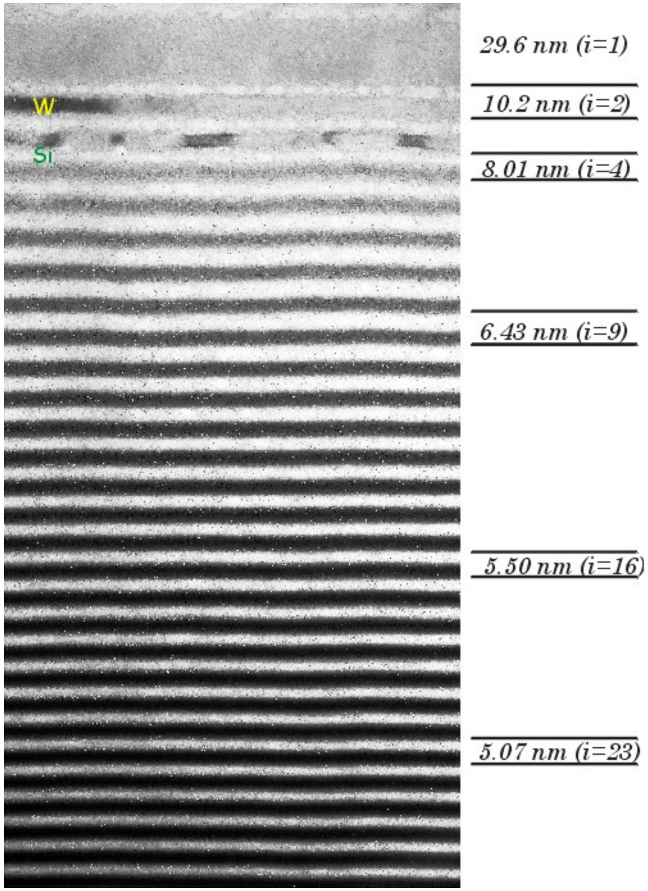


Depth-Graded Multilayers (DGML): by growing a film with a range of periods, broad energy response can be achieved.






W/SiC Depth-Graded Multilayer
Reflectance, R
Energy, E [keV]
0.0
0.2
0.4
0.6
0.8
20
40
60
80
100
Measured
Theoretical optical constants
Experimental optical constants


W
Si
29.6 nm (i=1)
10.2 nm (i=2)
8.01 nm (i=4)
6.43 nm (i=9)
5.50 nm (i=16)
5.07 nm (i=23)

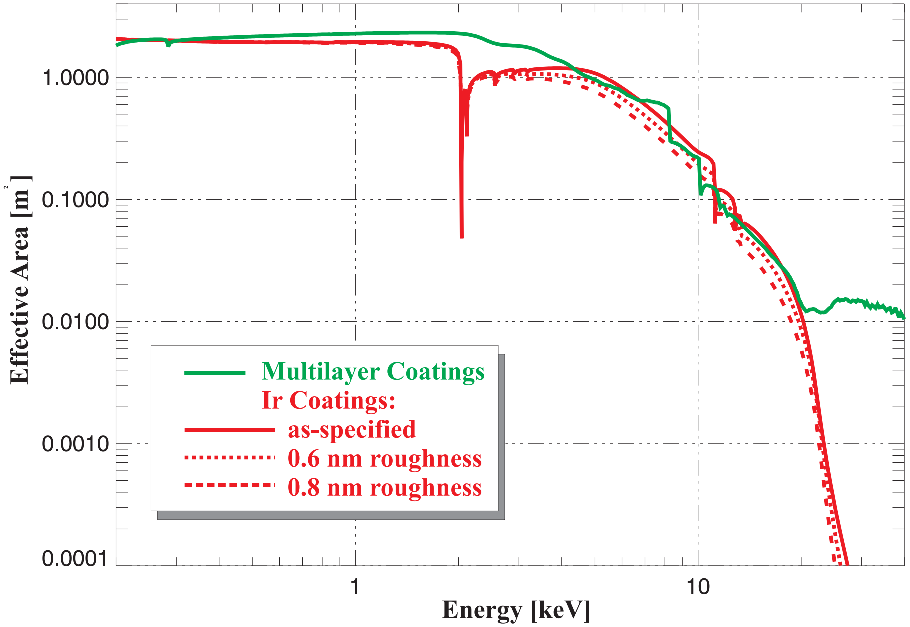
Multilayer design approach used for the Con-X SEP:

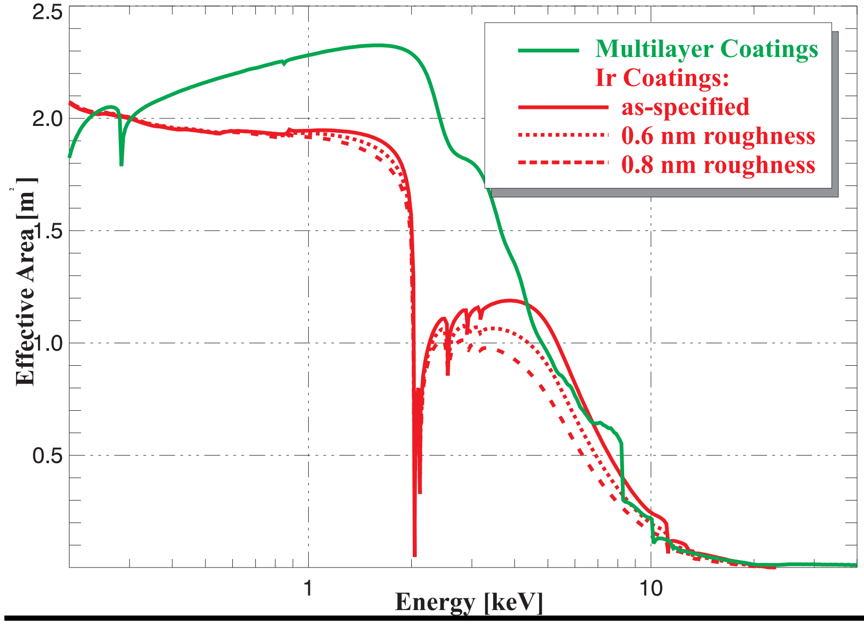
•'conventional' power-law DGML recipe

•material combinations, layer thicknesses and interface parameters that are realistic, i.e., can be made using current deposition technology

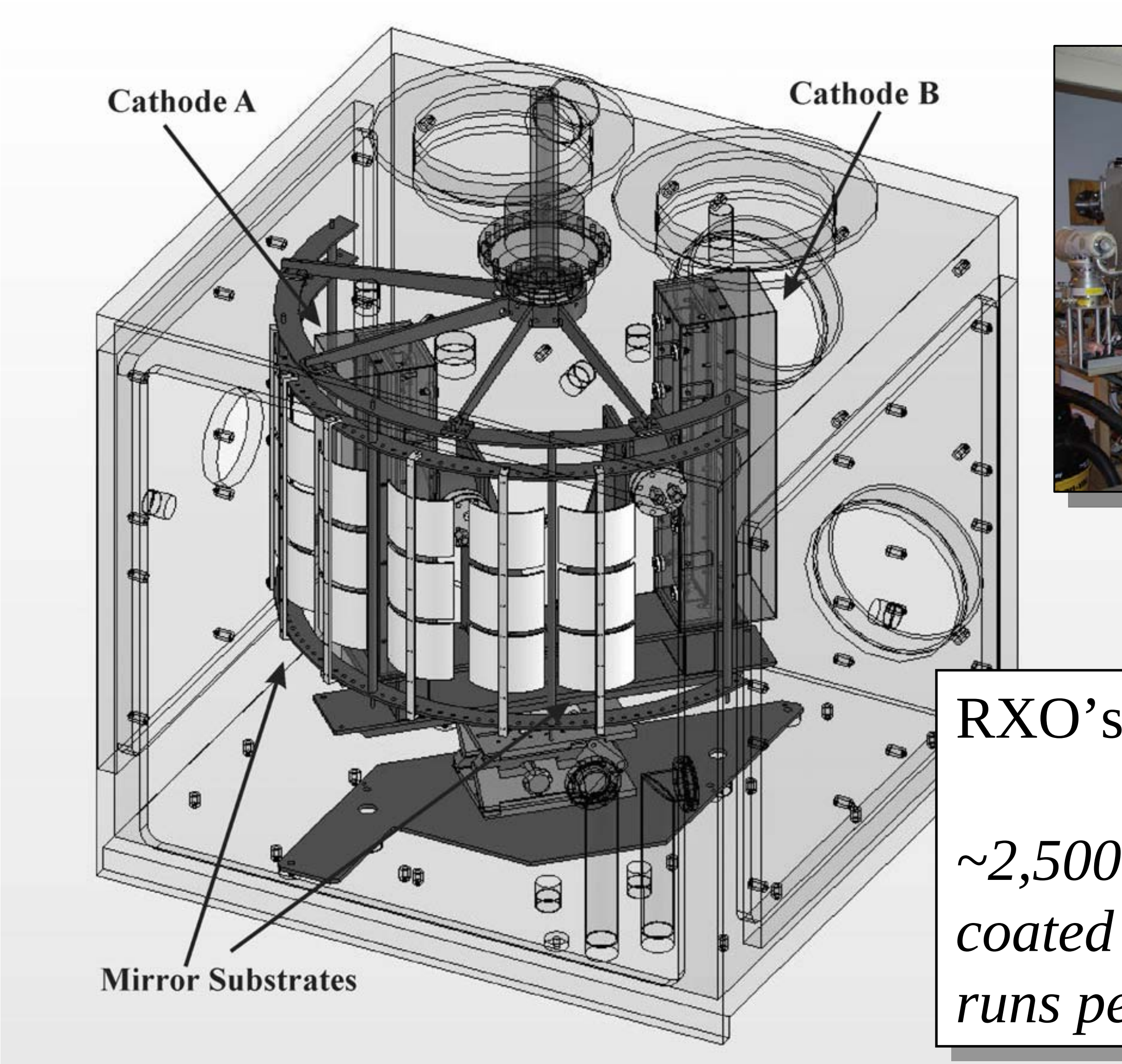
•DGML recipe customized (albeit 'manually') for each of the 163 SXT mirror shells, with graze angles in the range 0.217° – 0.937°

✍ resulting preliminary design is thus practical, but not necessarily optimal!





- Significant increase in effective area from ~0.3 keV – ~4.5 keV.
- ~100 – 200 sq. cm. effective area from ~20 – 40 keV.



RXO's coating facility

~2,500 sq. cm. area can be coated per run, with 1 – 2 runs per day.

1. Estimation of DGML stress on the optical figure, and comparison relative to Ir coatings?

Relationship between film stress, σ, and substrate deformation, i.e., change in radius of curvature (Stoney's equation):

$$\sigma = \frac{Y_s}{6}\frac{t_s^2}{t_f}\left(\frac{1}{R} - \frac{1}{R_0}\right)$$

where Y_s=substrate biaxial elastic modulus (~92 GPa for glass), t_f=film thickness, t_s=substrate thickness, and R is the substrate radius of curvature.

Don't yet know what the multilayer stress will be, but worst case should be σ=1 GPa. Taking t_s=400 μm, t_f=2 μm, R_0=355 mm, this gives R=275 mm. (In actuality it should be much less than this.)

In comparison, for a 50-nm-thick Ir film w/ σ=300 Mpa, R=354 mm.

In any case, once the change in radius is known and predictable it can be accommodated by fabricating the mirror shells such that the final radius R, rather than the initial radius R_0, has the required value.

2. Impact of surface roughness?

Surface roughness will degrade the reflectance of multilayer-coated mirrors just as it degrades front-surface (i.e., Ir-coated) mirrors.

But: new multilayer technology currently under development may be able to smooth surface roughness intrinsic to the glass.

3. Cost?

Pretty hard to say at this point, but perhaps about $5M, within a factor of 2.

4. What about increase from 10 – 20 keV?

Have not yet been able to increase the telescope response in this energy range.

But: the preliminary design shown here is far from comprehensive. Better multilayer designs may be found that do improve the response from 10 – 20 keV.